Impacts and Meteorite Organic Compounds

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The majority of meteorites that contain organic compounds are thought to originate in the asteroid belt. Impacts among asteroids and impacts between asteroids and comets with the planets generate heat and pressure that may have altered or destroyed preexisting organic matter (depending upon impact velocities). Very little is known about the impact-related chemical evolution of organic matter relevant to this stage of the cosmic history of biogenic elements and compounds. At Ames Research Center, research continues in an effort to understand the effects of impacts on organic compounds.

One experimental approach is to subject mixtures of organic compounds, embedded in the matrix of a meteorite, to simulated hypervelocity impacts using a vertical gun. By choice of suitable targets and projectile materials, the compounds are subjected to simulated impacts, resulting in various pressures in the range of 100 to 400 kilobar. Each pressure can then be converted by mathematical equations into the corresponding impact velocity that an actual asteroid or meteorite would have experienced. Most of these velocities are too high to obtain in the laboratory. After the laboratory impacts, the products are analyzed to determine the degree of survival of the organic compounds.

Four classes of organic compounds, known to be indigenous to carbonaceous meteorites, have been studied: organic sulfur, organic phosphorous, polyaromatic hydrocarbons, and amino acids. The sulfur compounds were sulfonic acids containing one to four carbons. The phosphorous compounds were phosphonic acids, also containing one to four carbons.

Results show that over the range of pressures the general trend is that the survival rates of compounds are inversely proportional to impact pressure (impact velocity). However, at lower pressures, 100 to 200 kilobar (approximately 1 to 2 kilometers per second (km/sec)), the sulfonic acids containing only one or two carbons show nearly complete survival. There was a significant drop in survival rates at approximately 300 kilobar for all organic sulfur and phosphorous compounds. Pressures of 300 to 400 kilobar (4 to 5 km/sec) resulted in survival rates of approximately 20 to 30% for all one- and two-carbon compounds, while the three- and four-carbon compounds survived at rates of approximately 0 to 10%. In the case of polyaromatic hydrocarbons and amino acids, a similar trend of decreasing survival rates with increasing pressure was observed. However, these two groups were less stable than the sulfur compounds at lower pressures.

These results indicate that significant amounts of meteoritic organic compounds would have survived impacts within the asteroid belt throughout solar-system history. In the context of asteroid impacts on Earth, the results also suggest that most of organic compounds would have survived in objects that experienced impact velocities near or below 4 to 5 km/sec.

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Biogeochemistry of Early Earth Photosynthetic Ecosystems: Production of Hydrogen and Carbon Monoxide

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For the first three-quarters of its history, Earth's biosphere consisted exclusively of microbial life. Most of this period was dominated by photosynthetic microbial mats, highly complex and organized communities of microorganisms that once covered the Earth. For two billion years, these mats were the primary biologic agents of global environmental change (for example, the oxygenation of the atmosphere) and the crucible for evolution of the complex macroscopic life forms we know today. Ames' Early Microbial Ecosystems Research Group studies the biology, chemistry, and geology of closely related modern microbial mats in order to better understand the important role played by their ancient counterparts.